MONTHLY NOTICES

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ROYAL ASTRONOMICAL SOCIETY.

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Dr. J. H. JEANS, PRESIDENT, in the Chair.

Eustace Vivian Bacon, M.B.E., M.A., 51 Drayton Gardens, London, S.W. 10;
David Dietz, 1146 Cleveland Heights Boulevard, Cleveland Heights, Ohio, U.S.A.;
W. K. Green, Ph.D., Director of the Observatory of Amherst College, Amherst, Mass., U.S.A.; and
William Hodge, F.R.C.O., 2 Newton Vale, Chapeltown Road, Leeds,
were balloted for and duly elected Fellows of the Society.

The following candidates were proposed for election as Fellows of the Society, the names of the proposers from personal knowledge being appended :—

Frederick Addey, B.Sc., M.I.E.E., Assistant Inspector of Wireless Telegraphy, G.P.O., Ryecroft, Chinbrook Road, Grove Park, London, S.E.12 (proposed by H. Knox-Shaw);
Alexander Williams Anderson, Commander R.N.R., G.H.Q., British Army, Cologne (proposed by R. A. Sampson);
Ernest Anthony Lonsdale Attkins, London District Manager's Dept., London and North Eastern Rly. Co. and 2 Outred Villas, Squirrels Heath, Essex (proposed by Theodore E. R. Phillips);

C. M. C. Bone, M.A., Surveyor General's Office, Pretoria, South Africa (proposed by R. T. A. Innes);

Dr. Willem Hendrik van den Bos, Leiden Observatory, Holland, and Union Observatory, Johannesburg, South Africa (proposed by W. de Sitter);

Philip Arthur Curry, B.A., A.Inst.P., Director of the Helwân Observatory, Egypt (proposed by H. Knox-Shaw);

William Stephen Finsen, Union Observatory, Johannesburg, South Africa (proposed by R. T. A. Innes);

David Lamont Forbes, 437 Smith Street, Durban, Natal, South Africa (proposed by R. T. A. Innes);

Capt. Henry Freyne, Nautical Surveyor and Examiner of Masters and Mates for the Irish Free State, 27 Eden Quay, Dublin, Ireland (proposed by M. H. Clarke);

Frederick Gawith, Hawera, New Zealand (proposed by A. C. Gifford);

Rev. Herbert Hedley, M.A., 17 Brockhill Road, Hythe, Kent (proposed by W. A. Parr);

W. W. Heinrich, Observatoire de l'Université tchèque, Prague-Smíchov, Czechoslovakia (proposed by A. S. Eddington);

Kiyotsugu Hirayama, D.Sc., Professor of Astronomy at the Imperial University of Tokyo, Astronomical Observatory, Azabu, Tokyo, Japan (proposed by F. W. Dyson);

Alan Patrick Mackerras, B.E., International General Electric Co., Schenectady, New York, U.S.A. (proposed by L. J. Comrie);

Sydney Briton Henry Manning, McLaren Flat, South Australia (proposed by C. J. Merfield);

William Ralph Mechaelis, Head Master of the Alexandra District High School, Alexandra, Otago, New Zealand (proposed by C. E. Adams);

Zeus A. Merfield, Research Physicist, University, Melbourne, Victoria, Australia (proposed by C. J. Merfield);

Patrick O'Dea, M.A., LL.B., Hawera, New Zealand (proposed by C. E. Adams);

William Tyler Olcott, Norwich, Connecticut, U.S.A. (proposed by Ernest W. Brown);

C. Parvulesco, Plœsti, Roumania (proposed by F. J. M. Stratton);

Frederick Charles Pilcher, Survey of India, Belmont, Norris Road, Richmond Town, Bangalore Cantonment, South India (proposed by E. A. Reeves);

Alexander Oliver Rankine, O.B.E., D.Sc., Director of Technical Optics Dept. and Professor of Physics, Imperial College of Science and Technology, London, S.W.7 (proposed by A. Fowler);

N. M. Shah, M.A., Principal of the New Poona College, Poona City, India (proposed by S. R. U. Savoor);

William Francis Herschel Waterfield, Nakusgs, British Columbia, Canada (proposed by Francisca Herschel); and

W. H. Watts, B.Sc., The Lydiate, Heswall, Cheshire (proposed by Harold Whichello).

Sixty-eight presents were announced as having been received since the last meeting, including, amongst others :—

Algiers Observatory, Catalogue de 9997 étoiles comprises entre -17° 50′ et -23° 0′ de déclinaison 1855 pour l'équinoxe de 1900.

Cape of Good Hope, Royal Observatory, Astrographic Catalogue, vol. 8.

Cape of Good Hope, Royal Observatory, Annals, vol. 13, pt. 1.

Royal Observatory, Greenwich, Observations of Stellar Parallax from photographs taken and measured . . . in the years 1913–1924.

Professor H. Dingle and Mr. F. Robbins were appointed auditors of the Treasurer's accounts for 1925.

A Study of the Nature of Spectroscopic Binaries.

By Otto Struve.

In a previous paper * I have shown that spectroscopic binaries of periods longer than 2·4 days, if arranged in order of increasing period, exhibit a continuously decreasing orbital velocity. This decrease agrees well with Kepler's third law, written in the form

$$K = CP^{-\frac{1}{3}} \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where P is the average period for a small group of binaries, K is the average semi-amplitude of the velocity curve, and C is a constant depending chiefly upon the average mass of the stars and upon the average value of the sine of the inclination.

For periods shorter than 2·4 days, the observed distribution of the K's differs radically from that required by equation (1). K decreases rapidly for the shorter periods, and only a few eclipsing binaries, with periods shorter than one day, are known that continue to obey equation (1).

Furthermore, I showed that the Cepheid variables do not follow equation (1) : K has a constant value for all periods (+16 km./sec.).

I suggested, therefore, that the stars which are known to have variable radial velocities consist of two groups. The majority obey Kepler's third law. These are beyond any doubt actual binaries, of the same sort as those observed visually. For periods shorter than 2·4 days the percentage of stars belonging to the second group and not obeying Kepler's third law increases rapidly as the period decreases. The nature of these stars must be radically different from that of the members of the first group. The fact that the stars of shortest periods have an average value of K almost identical with that of the Cepheid variables

* *Ap. J.*, **60**, 167, 1924.

(+16 km./sec.) makes it appear very probable that they are in some way related to such stars as δ Cephei or ζ Geminorum.

The material on which these results were based consisted of the orbits of 144 spectroscopic binaries, contained chiefly in a list by R. G. Aitken.* The small number of objects prevented me from subdividing the stars according to spectral type, although I recognised that some features of the relation connecting K and P must necessarily be obliterated by the well-known uneven distribution of spectral types along the axis of log (10P).

The new *Third Catalogue of Spectroscopic Binary Stars*, by J. H. Moore,† contains a large amount of new data. It seemed, therefore, desirable to revise my previous results and especially to investigate such properties of the curves as might have been lost in the material not classified according to spectral type.

In the present work I have utilised orbits of all the binaries contained in the *Third Catalogue*. Binaries in which slow variations of the velocity of the system are known to exist have been counted as two separate doubles. However, cases of short-period disturbances of the principal velocity curve, which are known to occur in certain spectroscopic binaries and which have usually periods equal to whole multiples of the principal oscillation, were in most cases disregarded, although they may be due to the existence of a third body.

In addition to the orbits contained in Moore's Catalogue, I have used several which have been published since its appearance, as well as a few others which are now being investigated at the Yerkes Observatory. The only star intentionally excluded here is 7 ε Aurigæ. Ludendorff's investigations,‡ as well as a long series of observations made at the Yerkes Observatory, prove that this star is quite exceptional and that much further work is needed to completely disentangle the slow variation of velocity from the short-period variation. This omission, however, is of no consequence to the final results.

In all, 272 systems were used, including 18 stars which were known to be Cepheid variables.

In order to test relation (1) for different spectral types I divided the 272 systems into five groups, as shown in Table I.

TABLE I.

Spectral Type.	Number of Systems.	Number of Cepheids.
O and B	90	2
A	64	0
F	56	8
G	39	8
K and M	23	0

The stars of each type were then arranged in order of period, and smaller groups of six objects each were formed. The average values of

* *The Binary Stars*, p. 296, 1918. † *L.O.B.*, **11**, 141, 1924.
‡ *Sitzungsberichte der Preussischen Akademie der Wissenschaften*, 1924, **9**, 49.

P and K for each group are given in Table II. Since the Cepheids behave differently from the other stars,* their velocities were excluded from every group, and are given separately.

TABLE II.

Spectral Types O *and* B *(Cepheids excluded).*

Interval of Period. d.		d.	Av. P. d.	No.	Av. K. Km./sec.
0·190	–	1·302	0·709	4	22·0
1·364	–	1·505	1·460	6	93·0
1·677	–	2·105	1·038	6	118·6
2·172	–	2·616	2·386	6	129·6
2·625	–	3·381	3·010	6	91·9
3·452	–	4·014	3·749	6	92·0
4·283	–	5·522	4·634	6	103·6
6·927	–	8·024	7·523	6	54·7
5·732	–	6·828	6·427	6	70·7
8·4	–	12·427	10·566	6	29·8
12·58	–	21·03	14·76	6	133·0
21·90	–	34·08	28·98	6	46·0
34·60	–	69·92	49·56	6	24·1
88·11	–	137·94	120·08	6	33·7
138·0	–	3504·0	885·8	6	31·2
			Spectral Type A.		
0·108	–	1·195	0·548	6	29·6
1·271	–	2·236	1·806	6	90·8
2·292	–	2·824	2·546	6	62·7
2·928	–	3·571	3·214	6	53·6
3·749	–	4·024	3·894	6	61·7
4·118	–	5·969	4·975	6	50·3
7·390	–	9·944	8·971	7	41·1
10·56	–	17·12	13·30	7	36·4
17·36	–	38·3	25·66	7	55·6
51·4	–	6570·0	1512·0	7	21·4
			Spectral Type F (Cepheids excluded).		
0·142	–	1·611	1·020	5	31·6
1·737	–	3·243	2·559	5	45·4
3·389	–	3·993	3·716	5	67·3
4·000	–	4·820	4·505	5	54·1

* *Ap. J.*, **60**, 170, 1924.

TABLE II.—*continued.*

Interval of Period. d.			Av. P. d.	No.	Av. K. Km./sec.
5·280	–	7·595	6·337	5	31·9
7·638	–	10·211	9·404	5	42·6
10·21	–	14·50	12·42	6	50·1
16·24	–	71·70	42·61	7	28·4
74·15	–	8519·0	2591·0	7	13·5
			Spectral Type G (Cepheids excluded).		
0·334	–	4·285	2·723	4	53·0
5·367	–	9·590	7·249	4	37·6
9·929	–	16·385	12·907	4	24·0
17·12	–	45·45	31·94	6	26·7
104·02	–	329·2	206·8	7	21·1
497·0	–	1375·0	820·2	7	13·5
			Spectral Types K and M.		
6·721	–	24·65	17·033	6	27·8
121·0	–	331·0	209·0	6	18·3
390·0	–	960·0	639·0	6	10·1
973·0	–	3848·0	2060·0	5	10·1

Cepheid Variables.

Average P.	No. of Stars.	Km./sec.	Sp. Type.
0·192	2	16·9	B
0·567	1	22·2	F
1·950	1	11·0	F
3·438	2	14·4	G
3·871	3	7·3	F
4·436	1	17·6	F
6·272	2	20·2	G
6·392	2	17·2	F
13·270	2	20·6	G
17·121	1	8·5	G

The results contained in Table II. are shown graphically in fig. 1. The abscissæ are given in units of log (10P), while the ordinate is proportional to K. In order to make the general run of the polygons more apparent I have smoothed them in one place : the tenth and the eleventh groups of spectral type B were combined into one point on the diagram. The general character of the curves is the same as that of the average curve obtained in my previous paper. For periods longer than about two and one-half days all five curves are in perfect agreement with relation (1), C remaining constant within each curve, but differing from

one curve to another. I have computed the numerical value of C for each group, beginning from the maximum of the curves, and have then obtained the average for each spectral type. This value of C can be used for the determination of average masses of spectroscopic binaries. For any double star we have the following relation :— *

$$(m_1+m_2)\sin^3 i=[3{\cdot}01642-10](K+K_1)^3P(1-e^2)^{\frac{3}{2}}.$$

Substituting in this equation the following values :— †

$$K_1=1{\cdot}25\ K,$$
$$e^2=0,$$
$$[\sin^3 i]_{\text{average}}=0{\cdot}65,$$
$$m_1+m_2=M,$$

we obtain

$$\log M=3\log C+[4{\cdot}2601-10].$$

This equation was used in order to compute M for different spectral types. The results obtained in this way will not directly represent average masses, because for each group the values of C were averaged, and the masses are referred to these mean values of C. Table III. contains the results.

TABLE III.

	Spectral Binaries.		Seares.		
			Dwarfs.		Giants.
Sp. Type.	C.	Mass.	Vis. Binar.	Single.	Single Giants.
		⊙	⊙	⊙	⊙
O and B	163·5	8·0	14·0	8·3	8·2
A	115·5	2·8	6·9	4·0	5·6
F	106·2	2·2	2·7	1·5	3·2
G	89·7	1·3	1·3	0·8	2·8
K and M	98·9	1·8	1·1	0·6	2·6

For comparison Seares' ‡ determinations are given in the last three columns. My values are systematically smaller than those of Seares for single giants and for visual binaries. However, they agree well with our general conceptions of stellar masses. The increase of mass for the last group (types K and M) must be due to the increasing relative number of giants among the spectroscopic binaries. While the mass of B-stars agrees well with that found by Seares, the later types, F to M, show larger masses than Seares' dwarf branch.

Seares has pointed out that the large masses of visual double stars may be due in part to selection, the more massive systems more readily showing orbital motion than the less massive ones. The same applies, however, also to the spectroscopic binaries. Although it is quite possible that some corrections for selection should be made, yet it seems very probable that the curves are depressed from some cause, thus

* R. G. Aitken, *The Binary Stars*, p. 203, formula (4).
† O. Struve, *Ap. J.*, **60**, 174, 1924.
‡ *Ap. J.*, **55**, 165, 1922; *Mt. Wilson Cont.*, 226.

leading to smaller values than those obtained by Seares. I am inclined to think that this effect is produced by the existence of quasi-Cepheids, stars similar to the spectroscopic binaries of very short period, which are frequently called the β Canis Majoris type. These stars may also be associated with the Cepheid variables—as are the stars similar to

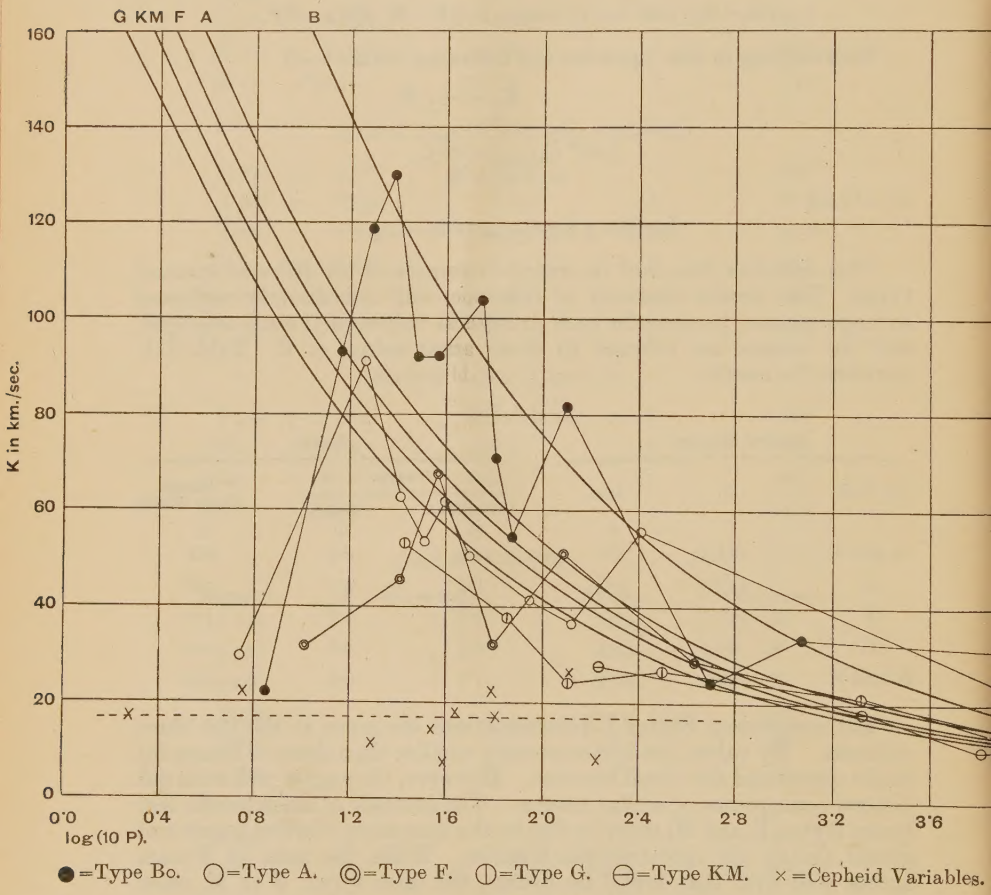


FIG. 1.—Relation between period and semi-amplitude of velocity-curve for various spectral types.

β Canis Majoris—in having small values of K which are independent of P. Whether or not such stars exist will depend on whether the discrepancy between the masses derived by Seares and those obtained from the spectroscopic binaries is real.

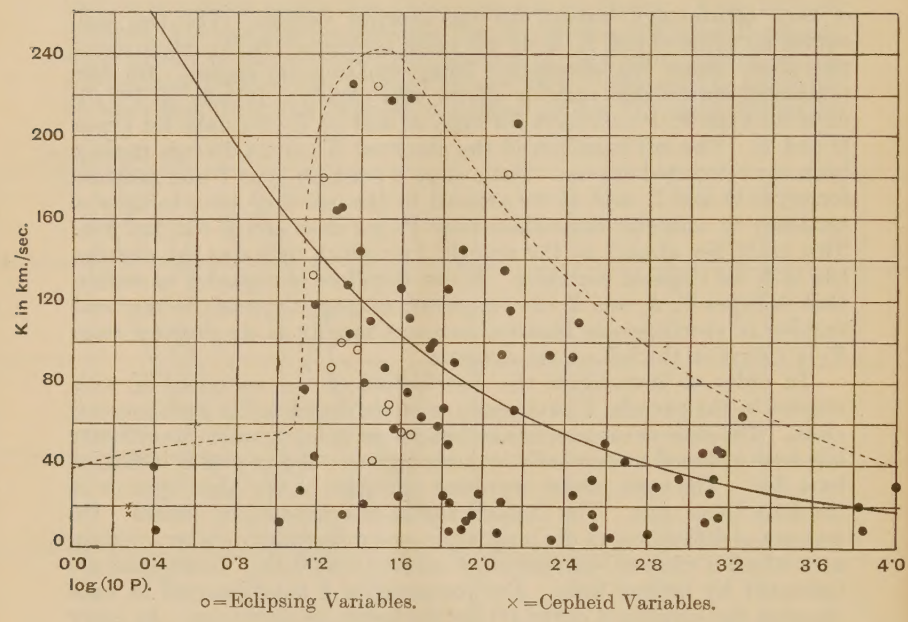
Fig. 1 shows the theoretical curves computed from (1) by substitution of the various values of C for each spectral type. It will be seen that the agreement of the distribution of K with the computed curves

is very satisfactory, except for the shortest periods. The two last curves for types G and K, M do not reach far enough to the left to show the point where the divergence from equation (1) begins. On the remaining curves this point is shown very clearly. It falls on P=3·5 days for type F, P=2·0 days for type A, and on P=2·4 days for types O and B. The left branches of the observed K-curves diverge rapidly from the computed curves. Their slope is least for type F and greatest for types O and B, and as we proceed to the left they seem to show a tendency to converge somewhere near P=0·5 days and K=20 km./sec. This point lies almost on the straight line which indicates the average run of K for Cepheid variables. It can therefore be regarded as certain that in types B, A, and F the proportion of quasi-Cepheids to the total number of spectroscopic binaries increases rapidly as we progress from P=2·5 days to the left on the diagram.

In order to investigate the distribution of the values of K with respect to the periods, I have made separate diagrams for each spectral class. The scale of the abscissa is the same as in fig. 1, while the ordinate has been reduced to one-half its previous size. Every star is indicated by a dot. The open circles represent variables of the Algol type or of the Beta Lyræ type. The Cepheid variables are shown by crosses. On account of differences in the inclination every diagram contains a certain area which is more or less uniformly covered with dots. These areas are indicated by broken lines. For convenience I have inserted in each diagram the computed curve (1) for the given spectral type. In every case the upper boundary of the area is a curve which can be expressed by equation (1). The corresponding value of C indicates the maximum mass for every diagram. Since the inclination must be nearly 90° for maximum values of K, the maximum mass can easily be computed. In general, there are very few stars which lie outside the upper boundary and which are unusual with respect to mass. Even the star BD+6° 1309, which, according to J. S. Plaskett, has a mass of probably more than 150 times that of the Sun, does not lie much higher than the limiting curve for O- and B-type stars.

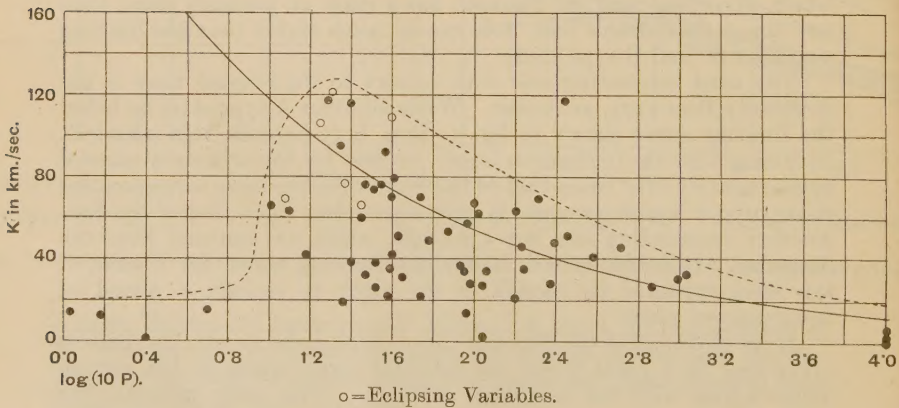
The most interesting star with respect to its unusual mass is undoubtedly Boss 1275, an A-star. While all other A-type stars lie below the limiting curve drawn in fig. 3, Boss 1275 extends high above it. Assuming that the inclination is 90°, we find for this system a mass of approximately fifty times that of the Sun, while the mass corresponding to our upper boundary curve is only about nine times that of the Sun. Another outstanding star is 7 ϵ Aurigæ, which was omitted from the diagrams. It would lie well above the limiting curve for F-stars, if this were extended far enough to the right to include a period of twenty-seven years.

If we move along the limiting curves from right to left, we come in every case to a point where the limiting curve begins to fall and no longer agrees with the computed curve (1). This point indicates the minimum period at which binaries of maximum mass can exist. The curve falls rapidly to small values of K and extends then horizontally to the left to include the systems of shortest periods, such as β Cephei, 12 Lacertæ, γ Ursæ Minoris, and others. The curves for types G and



The two stars above the upper curve are B.D. 6° 1309 (K=206 km./sec.) and β Lyræ (K=181 km./sec.).

FIG. 2.—Distribution of semi-amplitudes of velocity-curves for spectroscopic binaries of spectral types B and O.



The star above the upper curve is Boss 1275 (K=117 km./sec.).

FIG. 3.—Distribution of semi-amplitudes of velocity-curves for spectroscopic binaries of spectral type A.

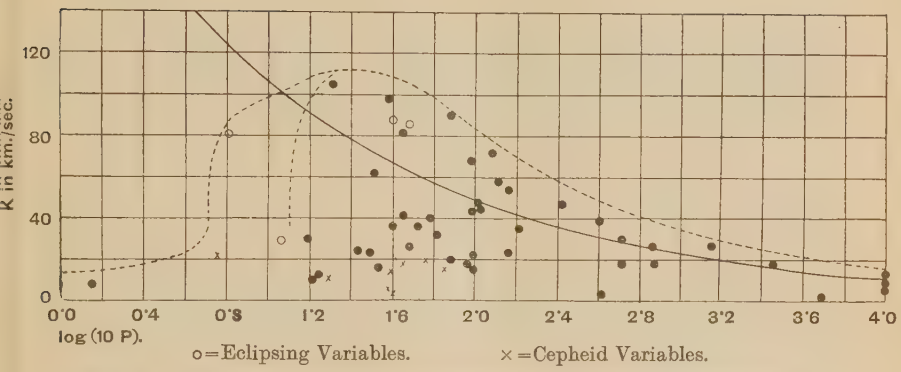
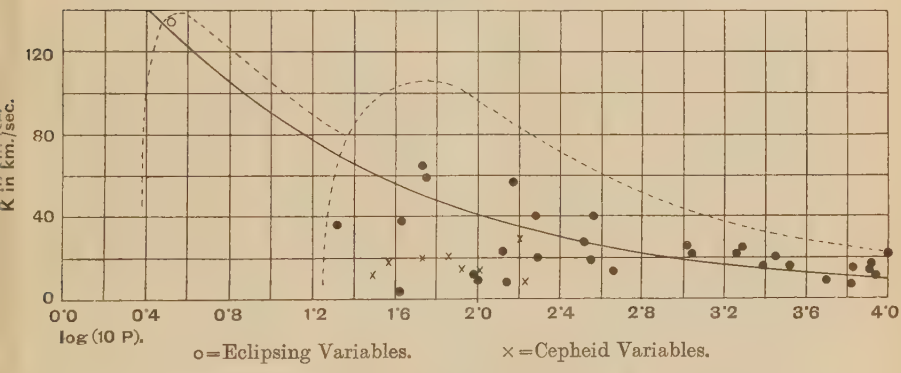


FIG. 4.—Distribution of semi-amplitudes of velocity-curves for spectroscopic binaries of spectral type F.



The star in the upper left corner of the diagram is W Ursæ Majoris (K=134 km./sec.).

FIG. 5.—Distribution of semi-amplitudes of velocity-curves for spectroscopic binaries of spectral type G.

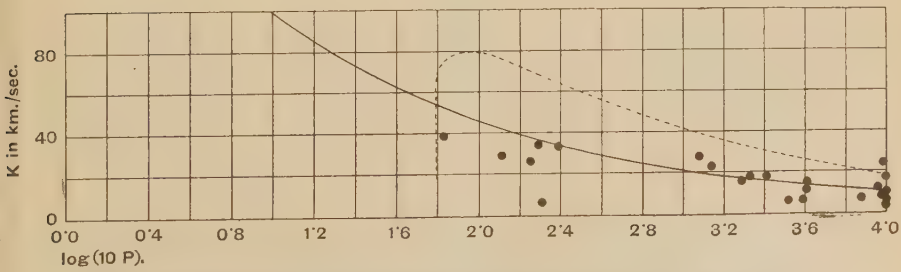


FIG. 6.—Distribution of semi-amplitudes of velocity-curves for spectroscopic binaries of spectral types K and M.

K, M are incomplete on account of the small number of stars used. Particularly striking in these diagrams is the absence of stars of the β Canis Majoris type; but this is perhaps due to the incompleteness of our observations. The maximum masses corresponding to the upper boundary lines of our diagram are compiled in Table IV.

TABLE IV.

Spectral type . .	O, B	A	F	G	K, M
Maximum mass . .	64	9	7	10	8

These values, as was previously pointed out, do not include stars of abnormally large masses. On account of the scantiness of the data this treatment seems more satisfactory than that based upon rigorous frequency curves.

If we concentrate our attention upon the B-stars alone, we notice that the left side of the boundary line is nearly perpendicular to the abscissa. Thus, there exists an abrupt change in the B-stars at P = 1·3 days. It is evident that this value of the period is the minimum at which real double stars of type B can exist.

The fact that on the right side of the boundary line the points are scattered nearly uniformly—in other words, that there is no thinning out of points in the diagram near P = 1·3 days—shows that the distribution is actually discontinuous. Evidently this discontinuity is due to the size of the components of the double stars. It seems reasonable to suppose that the larger the diameters of the stars, the larger will be the minimum possible orbit, and the longer will be the corresponding period, provided, of course, that the masses remain sensibly constant for every spectral type. Let us suppose that this condition is fulfilled. Then we could expect that the minimum possible distance between the two components, D min., can be expressed as a linear function of the average radius of the components ρ:

$$\text{D min.} = a\rho + b \qquad (2)$$

where a and b are constants to be determined from the observations.

Kepler's third law, written in the form

$$\frac{D^3}{d^3} = \frac{MP^2}{mp^2},$$

makes it possible to compute the value of D min. for various points on the boundary lines. The values of ρ can be taken from Bottlinger's curves.*

A rough computation for spectral types B, A, F indicates that in equation (2)

$$a = 2,$$
$$b = 0,$$

and that therefore the double stars are limited only by the actual contact

* *Veröffentlichungen der Universitätssternwarte zu Berlin-Babelsberg*, Bd. 3, Heft 4, Tafel II.; "Probleme der Astronomie," p. 343, 1924.

of their photospheres. In spectral type F there is some uncertainty in the left boundary line, due to the mixture of giants and dwarfs. Apparently, the smaller and lighter dwarfs can continue to exist at periods that would cause the larger and heavier giants to unite into one star. There is some indication that the boundary line of the dwarfs does not coincide with that of the giants, but lies somewhat to the left on the diagram.

For the later spectral types the evidence is less conclusive. Our data refer largely to giant systems, since the majority of the dwarfs are too faint for observation. In spectral type G the more massive giants stop at P=4·0 days, while the dwarfs, like W Ursæ Majoris, persist at least as far to the left as P=0·3 days. The two limits are tentatively indicated on the diagrams by broken lines. For K and M stars the limit occurs at about 6·5 days. This must refer to the giants alone, as there are probably very few dwarf binaries known that belong to these spectral types.

The fact that for the later types the dwarfs may have decidedly shorter periods than the giants probably accounts for the observation of Sanford that the average P of dwarfs is smaller than that of giants.*

As we have seen, types A and B show no such uncertainty in the left boundary line. At the same time it is evident from our diagrams that the dispersion in mass is considerable. More reliable information concerning the frequencies of stellar masses can be obtained from the distribution of the eclipsing binaries and β Lyræ variables. An eclipsing effect can be produced only if the inclination is very nearly 90°, unless the components are very close. In the immediate vicinity of the left-hand boundary line the great majority of stars will be eclipsing variables, and a glance at our diagrams shows indeed a very marked concentration of eclipsing stars near P min. Nevertheless, we would expect to find a maximum number of eclipsing binaries in the upper left corner of the outlined area, if the frequency distribution of the masses has one maximum corresponding to the average curve (1). In order to test this distribution of frequencies I superposed upon each of the diagrams (figs. 2–6) a set of curves computed by means of equation (1) for masses 0·5; 1·0; 2·0; 4·0; 8·0; 16·0; 32·0; 64·0; 128·0; 256·0 times that of the Sun. I then counted the number of open circles in the several regions separated by adjoining curves: Group I. denotes the area between the abscissa and the curve for mass 0·5, Group II. lies between curves M=0·5 and M=1·0, etc. The results are collected in Table V.

TABLE V.

Sp. Type.	Group I.	Group II.	Group III.	Group IV.	Group V.	Group VI.	Group VII.	Group VIII.	Group IX.	Group X.
O and B	1	2	3	2	1	1	..	..	..	..
A	1	1	1	1	2	..	..	..	..	..
F	2	..	..	2	..	..	..	..	..	..
G	..	1	..	..	..	..	..	..	..	..
K and M	..	..	..	..	..	..	..	..	..	..

* R. F. Sanford, *Ap. J.*, **61**, 332, 1925; **56**, 454, 1922. J. S. Peirce, *L.O.B.*, **11**, 132, 1924.

The number of stars in the various groups is small. Nevertheless, it seems that the maximum for spectral type B lies in Group III., indicating a maximum frequency of masses at 3·0 that of the Sun—a value which is only about a third of the average mass of eight times that of the Sun. This result confirms Hellerich's investigations * and shows that the frequency curve is either multimodal or has a considerable measure of skewness.

It is remarkable that in the B-type stars the minimum possible period is nearly the same for all objects, although the masses show a large dispersion. Since it does not seem probable that the constants a and b in equation (2) depend upon mass, I am inclined to believe that the dispersion in mass is compensated by an analogous dispersion in the sizes of the stars. Indeed, Bottlinger's diagram of stellar diameters † shows a considerable scattering for B-type stars from $\rho = 1{\cdot}5\odot$ to $\rho = 40\odot$, with a maximum frequency at or near $\rho = 3\odot$.

To test the frequency curve of spectroscopic binaries I have counted the total number of dots in groups of every 0·40 units in log (10P). The results are shown in Table VI. The Cepheids were also counted separately, as shown in the last line of the table.

TABLE VI.

Average, log 10P.	0·2.	0·6.	1·0.	1·4.	1·8.	2·2.	2·6.	3·0.	3·4.	3·8.	4·2.	4·6.
O and B	3	1	6	24	19	10	10	9	1	2	..	1
A	3	1	4	22	13	11	4	3	..	..	2	1
F	1	1	3	14	16	8	5	3	1	1	..	3
G	..	1	..	3	9	8	4	2	5	6	1	0
K and M	..	..	..	..	1	5	..	2	4	6	3	1
Cepheids	2	1	..	6	6	3	..	..	..	..	..	..

The frequency curves of the earlier types show at the extreme left a comparatively low maximum corresponding to the quasi-Cepheids or stars of the β Canis Majoris type. At P min. there is a rapid rise in the frequency curve, indicating that actual double stars begin there in large numbers. The rise is less sudden for the later types, probably on account of the dispersion caused by the simultaneous presence of dwarfs and giants. After maximum, which in the B's occurs quite close to the value of P min., namely, at 2·5 days, the curve goes slowly down and merges with the visual double stars at the extreme right of the table. For the B-stars the curve is fairly regular, but beginning with type A a third maximum is noticeable on the right side of the table. It increases in height for the later types and even surpasses the central maximum in types K and M. This third maximum in the frequency curve of spectroscopic binaries had also been noticed by Dr. Sven Wicksell,‡ but the material employed by him did not permit a differentiation of the spectral types later than A.

* *A.N.*, **220**, 257, 1924; **221**, 49, 1924.
† "Probleme der Astronomie," p. 343, 1924.
‡ *Meddelande från Lunds Astron. Obs.*, Band **6**, No. 63, 1924.

The frequency curves regarded *in toto* present an aspect that by no means can be attributed to a normal or Gaussian distribution. The curve has three maxima : at P=0·5 days, P=3 days, and P=400 days. The last line in Table VI. represents the frequencies of those Cepheids for which spectroscopic orbits are available. Its general character is the same as that outlined by Dr. Margarete Güssow.* There is a small maximum at 0·5 days and a more pronounced one at P=4 days. If we had constructed a frequency curve for all variables, excepting only those which are known to be due to eclipses, we would have found an additional maximum at P=300 days, † corresponding to the long-period variables. Joy ‡ has shown that the most typical long-period variable, Mira Ceti, is at the same time a spectroscopic binary with the same period as that of the light curve. It seems probable, therefore, that the long-period variables should also be included among the spectroscopic binaries. Their amplitudes of velocity variation are probably small and the detection of these variations is rendered difficult on account of the faintness of all of these stars at minimum light.

The close coincidence of the maxima of the frequency curves for spectroscopic binaries and for variable stars makes it appear probable that there exists some relation between these groups of objects. This is the more probable as in both frequency curves the third maximum depends in a striking way on the spectral type. It is practically absent from the earlier types and becomes very pronounced in the reddest stars. Various investigators have recently expressed the opinion that Cepheid variables are closely related to ordinary double stars. §

Quite recently Dr. J. H. Jeans || was led to suggest, from theoretical considerations, that Cepheids and long-period variables are binaries in the process of fission. According to him, the period of oscillation or pulsation, which finally leads to fission, does not coincide with that of rotation. The final orbital period of the binary after fission will be equal to the period of axial rotation of the parent body.

I have suggested in a previous paper ¶ that the rapid changes in the velocity curves and light curves of such stars as β Cephei, γ Ursæ Minoris, 12 Lacertæ, and others of the β Canis Majoris type may be accounted for by a superposition of axial rotation and pulsation. In these stars, then, we probably observe the phenomena predicted by Jeans's theory. The true Cepheid variables represent a further state in the process of fission, where a definite period has become prevalent. However, the smallness of K and its independence of P makes it certain that the separation is not complete. The actual disruption of the two bodies must be cataclysmic in nature. The spectral types change

* *A.G., Vierteljahrsschrift*, **59**, 171, 1925.

† Newcomb-Engelmann, *Populäre Astronomie*, 7 Auflage, p. 647, 1922; H. Dingle, *Modern Astrophysics*, p. 261, 1924.

‡ *Popular Astronomy*, **31**, 645, 1923.

§ Hellerich, *A.N.*, **224**, 277, 1925; Hoffmeister, *A.N.*, **225**, 201, 1925; Hagen, *A.N.*, **225**, 175, 1925; Guthnick, *Veröffentlichungen der Universitätssternwarte zu Berlin-Babelsberg*, **11**, 3, p. 129, 1918; Guthnick, *Die Naturwissenschaften*, **13**, 92, 1925; Henroteau, *Publ. Dom. Obs., Ottawa*, **9**, 87, 1925.

|| *M.N.*, **85**, 797, 1925.

¶ Dissertation, University of Chicago, 1923 (unpublished).

rapidly from F and G to B and A,* and the laws of elliptic motion become applicable. This would explain the sudden rise of the frequency curve of spectroscopic binaries, coinciding with that value of P which we have designated as P min. and beginning from which Kepler's third law (equation (1)) is fulfilled.

The question as to the cause of the three maxima in the frequency curve of spectroscopic binaries would then become one as to the causes of the three maxima in the numbers of variable stars. One could assume that three types of oscillations are possible, corresponding to these maxima. The shortest periods, like that of β Cephei, cannot actually result in fission because of the limitations imposed by the diameters of the components. Representatives of this group consequently do not obey equation (1). The two other groups consist both of stars in which fission has not occurred, as in the Cepheid variables, and of real double stars which obey Kepler's third law.

This scheme has a very important defect in that it does not provide a place for the ordinary visual double stars having periods as long as hundreds or thousands of years. Of course, it is possible that our third group has a very large dispersion, or that the orbits have been modified by some other perturbing factors. Another alternative would consist in assuming a completely different origin for the wide double stars, such as capture or formation from a common nebula. This is, however, not very probable, as there is no distinct break between ordinary visual double stars and such binaries as would be attributed to the third group.

Except for this obvious difficulty, Jeans's theory seems to fit the various characteristics of spectroscopic binaries remarkably well.

Summary.

The relation between period and semi-amplitude of the velocity variation was tested for spectroscopic binaries of various spectral types. For periods longer than two and one-half days this relation can be expressed by Kepler's third law written in the form $K=CP^{-\frac{1}{3}}$.

The average masses of binaries of various types were computed from the constants C.

The values of the shortest possible periods at which double stars can exist were determined for various spectral types. These values correspond to actual contact of the components.

The frequency curves of spectroscopic binaries of various types were determined.

Attention was called to the resemblance of this frequency curve to that of the variable stars, indicating that there exists some relation between variable stars and spectroscopic binaries.

Some of the consequences of this relation were discussed in the light of Jeans's fission theory for the origin of double stars.

* J. H. Jeans, *M.N.*, **85**, 798, 1925.

Yerkes Observatory :
1925 *October* 30.

Micrometrical Measures of Double Stars.

By Rev. T. E. R. Phillips, M.A.

The following measures have been made with the 8-in. refractor lent by the Society.

Star.	1925. R.A.	1925. Dec.	Mags.	Position Angle.	Distance.	No. of Nights.	Date 1900+.
	h m	° ′		°	″		
OΣ 12 (λ Cas)	0 27·6	+54 6	5·5, 5·8	160·1	0·55	4	25·37
Σ 25	0 14·9	15 35	8·5, 8·5	192·8	1·22	3	25·76
Σ 60 (η Cas)	0 44·5	57 25	3·7, 7·4	264·7	7·54	4	24·59
				265·3	7·76	3	25·61
β 495	0 44·8	18 17	7·5, 7·5	211·4	0·74	3	25·76
Σ 61 (65 Psc)	0 45·8	27 18	6·0, 6·0	116·8	4·25	3	25·76
Σ 73 (36 And)	0 50·9	23 13	6·1, 6·7	68·4	0·69	3	25·71
Σ 178	1 48·1	10 26	7·8, 7·8	198·7	3·07	2	25·07
Σ 186	1 52·0	1 28	7·2, 7·2	41·3	1·30	3	24·78
Σ 194	1 55·0	24 28	8·0, 8·3	271·6	1·14	3	25·77
OΣ 38 (γ² And)	1 59·3	41 58	5·4, 6·6	105·4	0·54	5	24·97
Σ 262 (ι Cas) AB	2 22·8	67 4	4·2, 7·1	249·6	2·34	3	25·05
AC	..	..	4·2, 8·1	111·9	7·35	3	25·05
Σ 425	3 35·4	33 53	7·3, 7·3	86·1	2·34	3	25·68
Σ 572	4 33·8	26 48	6·5, 6·5	197·4	3·68	3	25·11
OΣ 95	5 1·1	19 42	7·0, 7·6	318·2	0·76	3	25·05
Σ 644	5 5·2	37 13	6·7, 7·0	221·9	1·78	3	25·04
Σ 716	5 24·6	25 6	5·8, 6·6	202·5	4·77	3	25·06
Σ 748 (θ Ori) AB	5 31·6	− 5 26	7·0, 8·0	31·9	8·56	4	25·91
AC	..	..	7·0, 4·7	131·6	12·91	4	25·91
AD	..	..	7·0, 6·3	96·0	21·39	4	25·92
AE	..	..	7·0, 10·4	350·9	4·14	3	25·86
BC	..	..	8·0, 4·7	162·6	16·75	4	25·92
DB	..	..	6·3, 8·0	299·9	19·26	4	25·91
DC	..	..	6·3, 4·7	241·3	13·29	4	25·91
CF	..	..	4·7, 10·8	122·7	3·95	2	25·84
Σ 749	5 32·5	+26 53	6·4, 6·5	342·8	1·17	3	25·05
Σ 774 (ζ Ori)	5 37·0	− 1 58	2·0, 5·7	156·6	2·61	3	25·86
OΣ 545 (θ Aur)	5 54·6	+37 13	3·0, 7·5	332·6	2·84	3	24·78
Σ 881 (4 Lyn)	6 15·4	59 24	6·4, 7·9	113·7	0·79	4	25·84
OΣ 152	6 34·8	28 20	6·0, 7·8	37·2	0·73	2	24·15
Σ 948 (12 Lyn) AB	6 39·6	59 32	5·2, 6·1	106·1	1·80	4	25·83
AC	..	..	5·2, 7·4	306·5	8·28	3	25·81
Sirius	6 41·8	−16 37	−1·6, 8·4	62·6	11·06	2	24·22
				60·1	10·85	3	25·10
OΣ 159 (15 Lyn)	6 50·9	+58 32	5·1, 6·2	22·4	0·85	3	25·82

Star.	1925. R.A.	1925. Dec.	Mags.	Position Angle.	Distance.	No. of Nights.	Date 1900+.
	h m	° ′		°	″		
Σ 1066 (δ Gem)	7 15·7	22 7	3·2, 8·2	210·5	6·66	3	25·21
Σ 1110 (Castor)	7 29·8	32 3	2·0, 2·8	213·1	4·43	3	24·79
				212·0	4·54	5	25·35
OΣ 175	7 30·4	31 7	6·0, 6·6	329·0	0·65	3	25·02
Σ 1126	7 36·1	5 24	6·4, 6·7	149·8	1·20	3	25·03
Σ 1130	7 37·6	9 53	8·4, 8·9	179·0	0·83	2	25·26
OΣ 182	7 48·8	3 35	7·0, 7·5	28·1	0·88	3	25·27
Σ 1177	8 1·0	27 45	6·5, 7·4	351·3	3·19	4	25·23
Σ 1196 (ζ Cnc) AB	8 7·9	17 53	5·6, 6·3	251·4	0·63	4	24·09
				239·6	0·61	4	25·05
$\frac{AB}{2}$ C	..	..	5·1, 5·5	104·7	5·50	3	25·07
Σ 1291	8 49·7	30 52	5·9, 6·4	321·0	1·62	2	24·18
Σ 1334 (38 Lyn)	9 14·2	37 8	4·0, 6·7	231·8	2·61	3	25·86
Σ 1356 (ω Leo)	9 24·4	9 23	5·9, 6·7	131·5	0·87	2	24·11
Σ 1424 (γ Leo)	10 15·8	20 13	2·6, 3·8	117·6	3·72	5	25·37
Σ 1450 (49 Leo)	10 31·1	9 2	6·0, 8·7	155·9	2·27	3	24·30
Σ 1523 (ξ UMa.)	11 14·2	31 57	4·4, 4·9	86·3	2·22	4	25·93
Σ 1865 (ζ Boo)	14 37·6	14 3	4·4, 4·8	136·3	0·79	4	24·26
				136·7	0·87	7	25·31
Σ 1888 (ξ Boo)	14 47·9	19 25	4·8, 6·8	45·6	2·97	5	24·24
				41·3	3·01	6	25·41
Σ 1932 (1 Cor)	15 15·1	27 6	5·6, 6·1	27·9	0·56	4	25·32
Σ 1937 (η Cor)	15 20·1	30 33	5·6, 6·1	152·9	0·54	3	25·32
Σ 2055 (λ Oph)	16 27·1	2 9	4·0, 6·1	97·5	0·71	3	25·72
OΣ 338	17 48·6	15 20	6·6, 6·9	7·2	0·70	3	25·43
Σ 2272 (70 Oph)	18 1·7	2 31	4·3, 6·0	128·3	5·77	4	24·54
				127·6	6·01	5	25·46
Σ 2289	18 6·8	16 27	6·0, 7·1	228·0	1·12	3	25·79
Σ 2375	18 41·8	5 25	6·2, 6·6	116·3	2·45	3	25·79
Σ 2382 (ε^1 Lyr)	18 41·9	39 35	5·1, 6·0	7·5	2·86	4	25·58
Σ 2383 (ε^2 Lyr)	18 41·9	39 32	5·1, 5·4	115·6	2·22	4	25·58
Σ 2525	19 23·5	27 10	7·4, 7·6	303·4	0·97	4	25·54
Σ 2579 (δ Cyg)	19 42·6	44 57	3·0, 7·9	272·8	1·94	4	25·71
Σ 2605 (ψ Cyg)	19 53·8	52 14	5·0, 7·5	180·5	3·17	3	25·71
Σ 2695 (94 Vul)	20 28·7	25 33	6·2, 8·0	78·4	0·79	3	25·74
β 151	20 34·0	14 20	4·1, 5·4	4·1	0·54	4	25·77
Σ 2716 (49 Cyg)	20 38·0	32 3	6·0, 8·1	46·8	2·75	4	25·73
Σ 2735	20 51·9	4 14	6·2, 7·7	285·1	1·95	3	25·74
OΣ 437	21 17·7	32 8	6·5, 7·2	35·2	2·28	3	25·72
Σ 2799	21 25·2	10 46	6·6, 6·6	288·5	1·67	3	25·73
Σ 2822 (μ Cyg)	21 40·8	28 24	4·7, 6·1	147·0	0·94	5	25·72
Σ 2863 (ξ Cep)	22 1·6	64 15	4·7, 6·5	280·4	6·95	3	25·74
Σ 3042	23 48·1	37 29	7·0, 7·0	87·2	5·00	3	25·78
Σ 3050	23 55·7	33 19	6·5, 6·5	231·1	1·97	3	25·78

Headley Rectory, Epsom:
1925 December.

The Late Mr. Edwin Holmes' Double Stars. By Rev. T. E. Espin, M.A.

The late Mr. Edwin Holmes in 1901 and 1902 published in the *English Mechanic* several communications on known Double Stars, and various others that he deemed unrecorded. His observations were made with a reflector of somewhat over 12-in. aperture which he had made and mounted himself. Unfortunately the mounting was an altazimuth, and consequently his positions were often precarious. Letters passed between us, and some of his stars were measured and identified by me. But the greater number remained unidentified. From his published observations and private letters I collected his stars into a MS catalogue, and Mr. M. A. Ellison of Armagh kindly undertook to look them up with the 10-in. refractor and measure them. In some cases the 18-in. reflector was also used. Several, however, could not be found with either instrument, Mr. Holmes having probably mistaken the reference star. Unfortunately Mr. Holmes seems to have kept no observing book, and so it has been impossible to clear the matter up. The remaining stars are given in the following catalogue with the measures by Mr. Ellison or by myself, and marked in the column under Observer by El. and Es. respectively. The places were furnished by Mr. Ellison for the stars he measured, and the whole have been brought up to 1900.

No.	R.A. (1900).	Decl. (1900).	P.	D.	Mags.	Nts.	Date 1900.	Obs.	
	h m	° ′	°	″					
1	0 31·9	+33 17	147·5	14·81	10·3 12·0	5	24·92	El.	
2	3 21·6	59 34	51·2	5·12	9·0 10·5	2	13·11	Es.	
3	59·0	62 4	216·0	5·65	9·5 10·5	2	02·07	Es.	
4	6 8·8	19 12	17·9	21·99	10·7 11·0	4	24·98	El.	
5	13 26·7	36 50	163·4	7·30	9·1 9·5	2	01·84	Es.	
6	15 45·7	26 5	184·5	18·46	10·0 10·5	2	24·69	El.	
7	16 33·8	49 8	2·9	28·83	10·0 10·5	3	24·70	El.	AB
			82·9	81·8	C=11·5	3	24·70	El.	AC
8	56·6	31 7	167·9	18·43	11·0 11·3	2	24·70	El.	
9	17 50·8	39 30	278·6	4·91	8·4 11·0	3	22·67	Es.	
10	59·4	25 15	3·0	34·63	11·0 11·2	2	24·76	El.	
11	18 15·1	25 23	163·0	20·09	10·5 11·3	3	24·70	El.	
12	54·4	33 0	356·9	14·63	10·5 11·5	2	24·81	El.	
13	56·2	32 38	30·9	10·74	10·5 11·6	3	24·77	El.	
14	56·4	31 14	330·1	13·85	10·5 10·5	3	24·78	El.	
15	57·2	8 34	12·0	10·46	10·3 11·3	3	24·82	El.	
16	19 4·0	30 30	327·4	8·95	10·5 11·5	2	24·79	El.	AB
			248·9	54·28	C=11·6	4	24·82	El.	AC
17	7·9	38 40	205·5	6·74	10·5 10·8	2	22·69	Es.	
18	9·4	30 10	329·0	25·96	10·0 10·1	2	24·79	El.	
19	9·9	38 58	332·0	11·83	10·5 11·5	2	24·71	Es.	

No.	R.A. (1900).	Decl. (1900).	P.	D.	Mags.	Nts.	Date 1900.	Obs.	
	h m	° ′	°	″					
20	19 10·6	28 43	77·7	4·32	9·0 9·4	3	24·95	El.	
21	12·1	27 19	107·5	10·44	12·3 12·5	3	24·92	El.	
22	16·9	34 55	254·3	10·82	10·5 11·0	2	24·77	Es.	
23	22·6	21 0	46·4	16·65	10·5 11·0	2	24·78	El.	
24	29·6	8 11	308·9	14·93	8·5 10·0	5	24·92	El.	
25	30·4	52 45	75·3	18·34	8·5 9·5	2	24·81	El.	
26	37·7	11 35	316·7	9·42	11·0 11·5	3	24·84	El.	
27	39·3	12 8	168·4	10·91	11·1 11·3	2	25·71	El.	
28	39·6	12 9	344·7	17·33	10·7 11·7	3	25·71	El.	
29	39·7	12 10	263·7	16·38	10·5 11·2	2	25·70	El.	
30	40·7	10 52	315·0	10·20	12·1 12·3	2	25·62	El.	
31	44·6	36 55	292·9	10·05	10·7 11·5	2	24·73	Es.	
32	51·5	34 19	229·0	4·39	10·0 10·0	3	25·88	El.	
33	51·9	34 27	77·9	11·16	10·0 10·4	2	25·94	El.	AB
			76·4	10·95	9·5 10·0	2	24·80	Es.	
			284·0	14·90	C=11·0	3	25·94	El.	AC
			285·2	15·18	C=11·0	2	24·80	Es.	
34	52·3	34 41	11·8	9·83	10·0 11·0	3	25 95	El.	
35	53·8	34 38	272·1	6·97	9·8 9·9	3	25·95	El.	
			270·2	7·41	9·3 9·5	2	24·80	Es.	
36	55·3	35 23	232·0	5·74	11·0 11·2	3	24·85	Es.	AB
			50·6	10·74	C=13·0	2	24·84	Es.	AC
37	20 7·6	35 21	121·2	5·66	9·3 9·6	2	24·84	Es.	
38	59·2	36 21	261·5	11·80	7·5 11·0	3	24·79	Es.	
39	21 17·2	58 16	65·0	13·60	9·2 9·4	2	18·98	Es.	
40	17·3	22 15	18·0	13·48	10·7 11·0	4	25·95	El.	
41	23 28·0	21 33	287·4	7·72	10·8 11·0	3	25·03	El.	AB
			26·0	22·29	C=11·9	3	25·04	El.	AC

Notes.

1. 8′*f*, 5′*n* π Andromedæ.
3. Place of Σ 485. Holmes' double star is at P. 71°·2, D. 89″·9. He also detected the *comes* F. See *M.N.*, lxii. p. 402.
4. 2′*p* 71 Orionis.
6. Between δ Coronæ and Σ 1977.
7. 24′*p* 42 Herculis.
10. 8′*s*, 4′*f* Σ 2268.
11. 12′*p*, 8′*s* Σ 2309.
12. 16′*n*, 16′*f* β 648.
13. 15′*f*, 5′*n* γ Lyræ.
14. 30′*p* Σ 2441. The S. star probably the brighter.
15. 2′*p*, 1½′*n* Σ 2435.
16. Near Σ 2467.
18. 11′*f* Σ 2483.
20. Also in A.G. (Cambridge). Measured also by A. It is B.D.+28°·3253, not B.D.+28°·3276 as given in J.'s Catalogue.
21. 3′*f*, 1′*n* OΣ 371.
23. 6′*s*, 2′*f* Σ 2523.
24. 41′*p*, 5′*n* Σ 2544.
25. 6′*f*, 2′*s* Σ 2542.
26. 2½′*p* χ Aquilæ.
30. 18′ 15″*n* Σ 2570.

32. An earlier observation of Espin 200, also Scheiner 727.
33. Also Scheiner 730, 731.
35. Scheiner 745.
36. Scheiner 759.
37. Scheiner 968.
38. Scheiner 1380.
40. 3′*n*, 2′*f* OΣ 437.
41. 30′*s*, 14′*p* 71 Pegasi.

Observations of Comets 1925*j* (*Van Biesbroeck*) *and* 1925*k* (*Peltier-Wilk*), *made at the Royal Observatory, Greenwich.*

(*Communicated by the Astronomer Royal.*)

The observations were made with the Sheepshanks equatorial (aperture 6·7 inches) by taking transits over two cross-wires at right angles to each other, and each inclined 45° to the parallel of declination. Magnifying power, 55; Observer, A. C. D. Crommelin.

G.M.T. (new).	Comet—Star. R.A.	Comet—Star. Decl.	No. of Comps.	Log Factors of Parallax.		Deduced Positions of Comet for 1925·0.		Star.
			Comet 1925*j*.					
	s	″				h m s	° ′ ″	
10·03477	− 71·57	+ 29·9	6	9·617*n*	0·786	12 7 25·25	+27 48 20·7	*a*
			Comet 1925*k*.					
5·71878	−245·45	+108·4	1	9·377	0·830	19 29 59·72	+ 1 21 34·8	*b*
5·71878	−263·97	−847·4	1	9·377	0·830	19 29 58·78	+ 1 21 33·0	*c*
5·71969	− 42·57	+145·1	7	9·377	0·830	19 29 59·63	+ 1 21 29·5	*d*
6·71455	+ 81·68	+773·2	2	9·361	0·836	19 33 31·87	+ 0 8 50·3	*f*
6·71465	− 59·81	− 94·2	4	9·361	0·836	19 33 31·61	+ 0 8 52·7	*e*
7·73622	+ 2·63	−215·3	5	9·426	0·840	19 36 52·75	− 1 1 14·3	*g*
7·73676	+ 1·58	−817·2	4	9·426	0·840	19 36 53·17	− 1 1 23·7	*h*

Assumed positions of Comparison Stars for 1925·0.

	R.A.	Decl.	Authority.
	h m s	° ′ ″	
a	12 8 36·82	+27 47 50·8	Greenwich 1910 Catalogue.
b	19 34 5·17	+ 1 19 46·4	Abbadia Catalogue.
c	19 34 22·75	+ 1 35 40·4	Albany A.G. Catalogue.
d	19 30 42·20	+ 1 19 4·4	Abbadia Catalogue.
e	19 34 31·42	+ 0 10 26·9	Abbadia with P.M. in decl. −″·02.
f	19 32 10·19	− 0 4 2·9	Abbadia with P.M. − ˢ·001, −″·376 (E.B.L.).
g	19 36 50·12	− 0 57 39·0	2 Algiers Astrog. plates.
h	19 36 51·59	− 0 47 46·5	Boss P.G.C.

The observations are corrected for differential refraction, and for the effects of motion of the comets in R.A. and declination. They are not corrected for parallax.

A New Variable Star in Andromeda. By A. Stanley Williams.

R.A.=0^h $19^m.6$. Decl.=+30° 07′ (1855).

This was found, quite accidentally, when making an observation of a suspected variable on the night of 1925 Sept. 12. A reddish-coloured star of about the 10^{th} magnitude attracted attention because it was not marked on the working chart of the area. Re-examined on Oct. 10, it was found to have decreased in brightness by nearly three-quarters of a magnitude. From this time on the variable was followed more closely. It continued to diminish in brightness, and by Nov. 18 it had fallen to 13·0 mag.

Examination was made of some photographs taken with a 4·4-inch portrait lens with the following results :—

1899 Nov. 6 . .	Not visible, below 11½ mag.
,, 10 . .	,, ,, ,, 13 ,,
,, 29 . .	,, ,, ,, 11 ,,
1900 Nov. 18 . .	,, ,, ,, 12 ,,
,, 22 . .	,, ,, ,, 12 ,,
1091 Jan. 14 . .	,, ,, ,, 13 ,,
1902 Dec. 31 . .	10 mag.
1904 Oct. 7 . .	10 mag.

The star is evidently a long-period variable, and it would seem to have been nearly at maximum brightness on 1902 Dec. 31 ; on 1904 Oct. 7 ; and on 1925 Sept. 12. A period of about 318·7 days is suggested, with the following approximate elements of variation :—

Maximum=J.D. 2424406+$318^d.7$ E.

If these are correct, the next maximum should occur on or about 1926 July 28.

Polvarth, St Mawes :
1925 *November* 26.

Wireless Time-Signals. Changes in the French Issues.
By Professor R. A. Sampson, F.R.S.

Following a series of resolutions adopted at the meeting of the International Time Commission at Cambridge in July last, certain changes will be made in the issue of time-signals from radio stations in France, commencing on 1926 January 1.

The present series of signals from the Eiffel Tower (FL), Lyons (Doua, YN), and Bordeaux (Lafayette, LY) will be withdrawn, and will be replaced by the following series :—

No.	G.M.T.	Signal.	Station.	W.L.	
1.	8.0	International and Rhythmic Signals	FL	2,600	Spark
2.	,,	,, ,, ,,	LY	18,900	CW
3.	9.30	International	FL	2,600	Spark
4.	20.0	International and Rhythmic Signals	LY	18,900	CW
5.	22.45	Old Semi-automatic Signal	FL	2,600	Spark
6, 7.		Short wave emissions—see below.			

This series will be put into operation in the first instance for a period of four months, after which it is contemplated that No. 3 may be withdrawn and No. 5 replaced by an issue of the International and Rhythmic Signal from FL, simultaneously with that from LY at 20^h. By that time it is expected that the issue on spark from FL will be replaced by an issue on modulated CW.

In the meantime the issues Nos. 3 and 5 will take the same form as hitherto, and for ordinary users the only service which is withdrawn is the issue of the Old Semi-automatic Series from FL at $10^h\ 45^m$.

The form taken by the issue No. 1 is the following :—

(*a*) Preliminary signal.

*(*b*) Times of issue of rhythmic signal of the *previous day* as determined by the *Bureau International de l'Heure, Paris.*

(*c*) Commencing at $7^h\ 57^m\ 55^s$, the International Signal as hitherto, except that the three dashes which have constituted the time-signal are to be replaced by six dots, commencing at the seconds 55·0, 56·0, 57·0, 58·0, 59·0, 60·0 and lasting each about 0·2 sec.

(*d*) Commencing at $8^h\ 1^m\ 0^s$, a new rhythmic issue of 306 signals, falling as follows :—

$1^m\ 0^s$, 1st dash followed by 60 dots.
$2^m\ 0^s$, 62nd ,, ,, ,, ,,
$3^m\ 0^s$, 123rd ,, ,, ,, ,,
$4^m\ 0^s$, 184th ,, ,, ,, ,,
$5^m\ 0^s$, 245th ,, ,, ,, ,,
$6^m\ 0^s$, 306th ,, .

The commencements of all these signals are to be evenly spaced : the commencements of the dashes are intended to fall precisely at the commencements of the seconds of mean time, and they will be each about two-fifths of a second in duration; the dots will be about one-fifth of a second in duration.

Besides these issues upon the wave-lengths hitherto employed by FL and LY respectively, issues Nos. 6 and 7 will be made at 8^h and at 20^h from FL, on *short wave-lengths,* namely, 32 metres and 75 metres, on the same pattern as the issues Nos. 2 and 4 above, during the probationary period of four months. After that, it is contemplated that one or other of these wave-lengths may be suppressed and the other retained permanently for issue in addition to the series 1–5 above.

* Later intimation from Paris places (*b*) subsequent to (*d*). The convention adopted is, *e.g.*, an issue 014 indicates that the 1st or 306th signal was passed 0·14 sec. late; 991 indicates that it was passed 0·09 sec. early.

A period of probation of four months has been adopted in order to ascertain how far the new issues meet both general and scientific requirements.

Any comments which are the result of experience on the working of the new issues, or upon the abolition of the old issues, should be addressed either to *M. le Directeur, Bureau International de l'Heure, Observatoire National, Paris, XIV^e^*, or to the communicator of this note.

They should arrive not later than the beginning of March.

Royal Observatory, Edinburgh :
1925 *December* 10.